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The Bald Eagle in Southeast Alaska

Winifred B. Sidle, Lowell H. Suring
and John I. Hodges, Jr.

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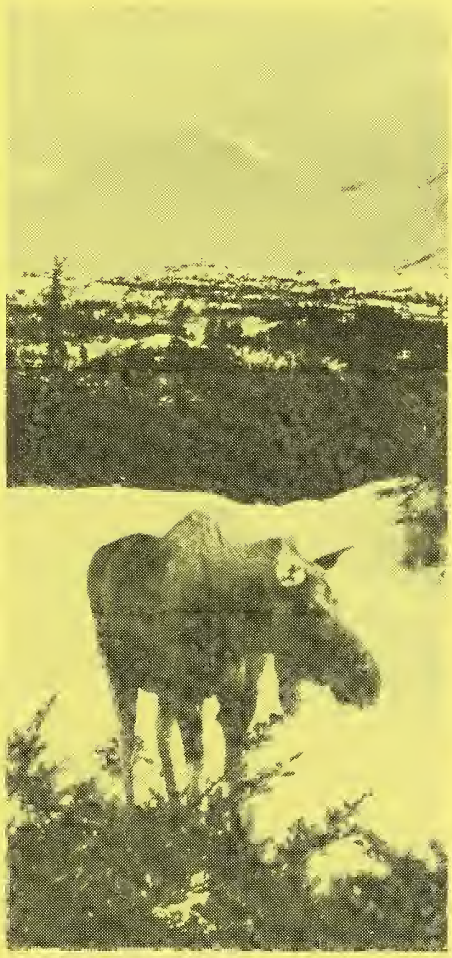

Abstract

The National Forest and adjacent lands in southeast Alaska support a breeding population of at least 10,000 bald eagles. This paper reviews the status and biology of the population, and the relationships of the bald eagle to management of the National Forest lands in southeast Alaska. A habitat suitability model is presented to help managers identify key areas of bald eagle breeding habitat and evaluate existing and potential habitat condition. The paper is intended to facilitate application of the bald eagle as a management indicator species on the National Forest lands of Alaska.

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CONTENTS

TABLES

FIGURES

The Bald Eagle in Southeast Alaska

Winifred B. Sidle[1]
USDA Forest Service
Juneau, Alaska

Lowell H. Suring[2]
USDA Forest Service
Ketchikan, Alaska

John I. Hodges, Jr.
U.S. Fish and Wildlife Service
Juneau, Alaska

November 1986

[1]Currently, USDA Forest Service, Washington, D.C.
[2]Currently, USDA Forest Service, Juneau, Alaska.

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Introduction

Southeast Alaska is an area of coastal mainland and offshore islands occurring north of Dixon Entrance, South of Yakutat, and east of the 41st meridian (Fig. 1). This area is topographically isolated from Canada and the rest of Alaska by extensive mountain ranges to the east and north. To the south, southeast Alaska is contiguous with the coastal rain forest that extends along the coast of British Columbia and into the Puget Sound area of Washington. Southeast Alaska is characterized by a cool moist climate with year-round precipitation that averages 100 inches (254 cm) annually (USDA Forest Service 1979). Forests, predominantly old growth, occur on approximately 10.3 million acres (25.4 million ha) or nearly half the total land area of southeast Alaska. Western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*) comprise over 90 percent of the forests of southeast Alaska (USDA Forest Service 1979). Nonforested lands of southeast Alaska include muskegs, grass-sedge meadows, alpine tundra, and extensive areas of rock and ice. The majority of the lands of southeast Alaska are part of the Tongass National Forest. The Tongass, at 16.8 million acres (41.5 million ha), is the largest Forest in the National Forest System.

The bald eagle (*Haliaeetus leucocephalus*) figures prominently in the management of the forested lands of southeast Alaska. In part, this emphasis stems from the importance of southeast Alaska as a major producing area of bald eagles. The breeding population, estimated at around 10,000 birds (U.S. Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data), represents the highest density of nesting bald eagles in North America (Hodges and Robards 1982). In distribution and abundance, the population of bald eagles that inhabits southeast Alaska today is believed to be similar to the population of presettlement times. Opportunity exists to maintain this productive population through careful consideration of its needs in all aspects of land-use planning and management.

The bald eagle is a species of national significance. In addition to its general appeal as the national symbol, the bald eagle has special religious significance to some Native American cultures. The sensitivity of the bald eagle to environmental conditions has exerted a heavy toll on eagle populations throughout the lower 48 states. Environmental pollution, habitat loss, persecution, and human encroachment have brought about serious population declines and extirpation of the bald eagle from large portions of its historic range (Evans 1982). The scarcity of the bald eagle provides only limited opportunity for viewing in most states where it occurs. In contrast, bald eagles are conspicuous throughout coastal southeast Alaska during the summer, and at food concentration areas in fall, winter, and spring. Thus, there is a superb opportunity to observe, photograph, and enjoy bald eagles in southeast Alaska.

Given the importance of the bald eagle population of southeast Alaska, it is appropriate that the species has been featured in land-use planning on the Tongass National Forest (USDA Forest Service 1979). Recently, the bald eagle has been proposed as a management indicator species for all National Forest lands in Alaska (Sidle and Suring 1986). As a management indicator species, the bald eagle will be used in land-use planning to establish habitat management objectives and to evaluate the short and long-term effects of management activities on habitat capability. These applications require current knowledge on the biology of the bald eagle and its relationships to habitat, as well as quantitative tools to evaluate existing and potential habitat condition.

The purpose of this paper is to promote the effective application of the bald eagle as a management indicator species on National Forest lands of Alaska. The information in this paper was compiled in a cooperative effort between the U.S. Fish and Wildlife Service, which has primary responsibility for the protection of the bald eagle in Alaska, and the USDA Forest Service, which is primarily responsible for administering the National Forest lands in Alaska, including the habitat of bald eagles. Part I reviews the status and biology of the bald eagle in southeast Alaska and its relationships to land management. Part II presents a habitat suitability model that managers may use to identify key areas of habitat and to quantify existing and potential habitat quality.

Fig. 1. Map of southeast Alaska.

Part I. Status, Biology, and Habitat Relationships of the Bald Eagle in Southeast Alaska

Status and History

Alaska is believed to support a breeding population of at least 20,000 bald eagles (U.S. Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data). Approximately half of the population occurs in the coastal environment of southeast Alaska. Other areas supporting eagles include south-central Alaska, interior Alaska, the Aleutian Islands, the Alaska Peninsula, Kodiak and Afognak Islands, Cook Inlet, and the Bering Sea (Table 1). Neighboring coastal British Columbia also supports an abundant breeding population, estimated to include at least 9,000 birds (Hodges et al. 1984).

In all states where it occurs except Alaska, the bald eagle is classified as an endangered or threatened species and receives federal protection under the Endangered Species Act of 1973[1]. Although the bald eagle in Alaska is classified as neither threatened nor endangered, the species is protected under the Bald Eagle Protection Act of 1940[2] (as amended) and the Migratory Bird Treaty Act[3]. The Bald Eagle Protection Act makes it illegal to take, possess, disturb, or molest eagles, eagle parts, eggs, or nests.

The bald eagle has not always been protected in Alaska. A bounty was enacted by the Territorial Legislature in 1917 to prevent alleged damage to the fishing and fox-farming industries (Kalmbach et al. 1964). Alaska was exempted from the Bald Eagle Protection Act of 1940 while this bounty was in effect. Approximately 128,000 bald eagles were killed between 1917 and 1952, when the bounty was repealed (Robards and King 1966). About 80 percent of the killing occurred in coastal southeast Alaska, and appears to have depressed population levels substantially. Densities of bald eagles reported in 1941 were only half of population levels today (Hansen and Hodges 1985). Recovery of the population following the repeal of the bounty is attributed to the availability of productive habitat and abundant food throughout coastal southeast Alaska.

Since 1981, bald eagles in southeast Alaska have been used as a source of transplant stock to restore breeding populations in portions of historic bald eagle range within the lower 48 United States. Most of the transplants have occurred through a cooperative agreement among the State of New York, the U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, and the USDA Forest Service. From 1981 to 1985, 133 nestling bald eagles were taken from nests within selected areas of southeast Alaska and moved to New York State. The birds were hand-reared to fledgling stage through a process called "hacking" and released into the wild (Nye, in press). Sixteen of 30 nestlings collected in southeast Alaska in 1986 were taken to New York for release. Of the remaining 1986 captures, 9 were taken to Missouri and 5 to Tennessee (Nye 1986).

Throughout the transplant program, nest productivity has been monitored in the removal area and a control area to identify possible effects on bald eagle productivity (Cain et al. 1982). Based on this information, the U.S. Fish and Wildlife Service has recommended that up to 30 bald eagles may be collected in southeast Alaska each year for release in other geographic areas (Nye 1986).

Table 1. Estimated minimum numbers of breeding bald eagles in eight regions of Alaska. (Source: U.S. Dep. Interior, Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data).

Region	Number	Percent
Southeast Alaska	10,000	50
South-central	3,000	15
Cook Inlet	250	1
Alaska Peninsula	1,500	8
Kodiak and Afognak	1,050	5
Aleutian Islands	1,800	9
Bering Sea	200	1
Interior	2,200	11
Total	20,000	100

Identification

The bald eagle is a large, soaring bird that is most easily identified by the bright white head and tail. Males and females have the same coloration, though they differ in body size. Kalmbach et al. (1964) recorded dimensions and weights of 108 bald eagles collected in Alaska, and concluded that they are generally larger than populations of the lower 48 states. Mean weight and wingspread of adult Alaskan females was 11.8 pounds (5.3 kg) and 88.4 inches

[1] 16 U.S.C. ss1531-43 (Supp. IV) as amended by P.L. 94-359,90 Stat. 913.
[2] 16 U.S.C. ss668-668d (1970 and Supp. IV 1974).
[3] 16 U.S.C. ss703-11 (1970 and Supp. IV 1974).

(224.5 cm). Adult males, which are usually smaller than females, averaged 9.3 pounds (4.2 kg) and 82.8 inches (210.3 cm).

Immature bald eagles are mottled brown and white, with considerable variation in mottling pattern among birds. The head undergoes a predictable transition from brown feathers, brown eyes, and dark beak at fledgling, to white head, yellow eyes, and yellow beak at maturity 5 years later (Southern 1964). The tail, which is dark or mottled in immature birds, turns white at maturity. Immature bald eagles may be confused with adult golden eagles (*Aquila chrysaetos*). When soaring, bald eagles usually hold the wings flat, whereas golden eagles usually soar with the wings held up at a slight angle (Armstrong 1980). The bald eagle's legs are unfeathered for 3 to 4 inches (7 to 10 cm) above the toes, whereas the legs of golden eagles are feathered to the toes.

Biology

Distribution and Movements

The population of bald eagles is widely dispersed throughout southeast Alaska during the breeding season. Bald eagles that breed along the coast tend to remain close to their breeding territory throughout the year if food is available. When not involved in nesting activities, however, these birds may temporarily move to feed at abundant sources of food. Large concentrations of bald eagles, including both breeders and non-breeders, occur at specific feeding areas during fall and winter. The largest of these concentrations occurs in the Chilkat Valley, along the highway north of the city of Haines in the northwest corner of southeast Alaska. More than 3500 eagles have been counted in the Chilkat Valley at the peak period (October to December) of concentration (Hansen et al. 1984). The birds remain in this area to feed on a late and abundant run of chum salmon (*Oncorhynchus keta*) that occurs in fall and winter.

Bald eagles may also concentrate at feeding grounds in the spring. On the Stikine River and estuary in central southeast Alaska, up to 1500 birds have been observed during the peak concentration period in April (USDA Forest Service, Tongass National Forest, Petersburg, Alaska. Unpublished data). The birds travel to the Stikine to feed on spring runs of eulachon (*Thaleichtys pacificus*), a small marine fish that travels up major mainland rivers to spawn. In the Chilkat Valley, bald eagles gather at the mouth of the river during spring to feed on spawning eulachon (Hansen et al. 1984).

Specific information on the movements of bald eagles in southeast Alaska is limited. Hodges et al. (in press) captured 31 bald eagles along the Chilkat River from 1979 through 1982 and equipped them with radio transmitters. The sample included 8 first-year birds (fledglings caught in the fall of their hatch year); 7 immatures (more than 6 months old but too young to have a predominantly white head and tail); 2 subadults (having a predominantly white head and tail but with the eye-stripe at least partially remaining); and 14 adults (with all white head and tail). The radioed eagles remained in the Chilkat Valley until food resources diminished because of ice buildup along the river or because the salmon run declined. The immature and first-year birds dispersed southward along the coast after leaving the Chilkat feeding grounds, with the majority (73 percent) reaching coastal British Columbia and Washington. The greatest distance moved (930 miles [1500 km]) was observed for a bird that left the Chilkat Valley on 29 November and was recovered 57 days later on the southwest coast of Washington. A different pattern of movement was observed for the adult and subadult eagles after they left the Chilkat feeding grounds. These birds remained in northern southeast Alaska, mostly within 200 miles (320 km) of the Chilkat Valley, throughout the breeding season. These observations led Hodges et al. (in press) to hypothesize that adult bald eagles, especially breeders with territories, may be resident in southeast Alaska. They will move up to around 185 miles (300 km) to exploit abundant food sources such as salmon, eulachon, or Pacific herring (*Clupea harengus*), but otherwise tend to remain close to their breeding areas.

The findings of Hodges et al. (in press) on the movements of radioed bald eagles led Hansen et al. (1984) to conclude that: 1) the majority of eagles that occur in the Chilkat Valley in fall and winter are probably from the southeast coastal region of Alaska, rather than from interior regions to the north; (2) eagles that occur in the fall tend to stay until food becomes scarce; and (3) the Chilkat Valley is a destination for northbound eagles, rather than a stopover point on a longer migration route.

Food Habits

Throughout their range, bald eagles are opportunistic in their use of available food resources. Fish is the dietary mainstay of bald eagles in southeast Alaska, as reported by Kalmbach et al. (1964) in their analysis of nearly 500 eagle stomachs collected in southeast Alaska from 1940 to 1946. Fishes averaged 65.7 percent of the year-round diet, although a variety of foods were taken (Table 2). These included birds (18.8 percent), mammals (1.2 percent), invertebrates (2.0 percent) and carrion (12.3 percent). The importance of fish in the diets of south-

east Alaskan eagles has also been reported in studies in the Chilkat Valley (Hansen et al. 1984) and the Robert Islands, 85 miles (137 km) south of Juneau (Ofelt 1975).

Foraging methods of bald eagles include scavenging, hunting live prey, and stealing food from conspecifics and other species of fish-eating birds (Evans 1982). Hansen et al. (1984) reported that the bald eagles along the Chilkat River, during fall and winter, most often fed on carcasses of salmon that had died naturally after spawning. In summer, the eagles fed on live fish as well as carcasses. Hansen (1986) studied food pirating among wintering bald eagles in the Chilkat Valley. The study provided evidence that bald eagles assess the value of a food item, and the size and hunger level of a prospective contestant, before attempting to steal food from a conspecific. Pirating was more common in large adult birds, whereas small or young birds were more likely to forage for unclaimed prey. Based on study results, Hansen (1986) concluded that pirating is adaptive even when food is abundant.

The gregarious feeding behavior of bald eagles is believed to be an important adaptation (Stalmaster et al. 1985). Feeding activity by individual bald eagles attracts and stimulates feeding by others, resulting in large groups feeding at the same time and place. This behavior may increase the chances for all members of a flock to locate food (Stalmaster et al. 1985).

The ability to locate and exploit ephemeral concentrations of food is an important survival strategy for bald eagles (Hansen et al. 1984). Throughout southeast Alaska, runs of spawning fish are an important seasonal source of food. Spawning anadromous fishes, including pink (*Oncorhynchus gorbuscha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and chinook (*O. tsawytscha*) salmon, travel upstream in summer and fall and are heavily used as food by bald eagles (Kalmbach et al. 1964). Spawning runs of herring and eulachon are exploited in spring. Eulachon usually spawn in or near the mouth of large rivers, such as the Stikine and Chilkat Rivers, whereas herring concentrate in intertidal areas to spawn. In late fall and winter bald eagles move to traditional winter feeding areas, such as the Chilkat River in southeast Alaska and the Skagit and Nooksack Rivers in northwestern Washington (Servheen 1975, Stalmaster et al. 1979), to feed on late runs of spawning salmon.

Population Size and Density

The first aerial census of the breeding population of bald eagles in southeast Alaska, conducted in 1967, was based on 30 plots (each 64 mi^2 [166 km^2] placed at random locations along the coastline (King et al. 1972). Birds of adult plumage that were perched along the shore were assumed to be breeders (i.e., birds that contribute to the reproductive effort of the population in a given year). These plots were recensused in 1977, and a stratified random sampling procedure was applied to both the 1967 and 1977 data. These analyses provided total population estimates of 7,230 ($\pm$896) in 1967 and 7,329 ($\pm$894) in 1977. Significant differences were not found between the 1967 and 1977 population levels (Hodges et al. 1979). The most recent aerial census, conducted in 1982, estimated the breeding population of bald eagles in southeast Alaska to be 9,974 + 1,884 (U.S. Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data.) The aerial census, though useful for enumerating the breeding population, does not account for subadult and nonbreeding adult bald eagles. This segment of the population tends to be distributed nonrandomly at this time of year, in response to local runs of spawning fish (James G. King, personal communication, 1986).

The population of breeding bald eagles is dense and widely distributed along the coastline of southeast Alaska. Given these conditions, identification of individual breeding territories is difficult, and breeding density is normally expressed as numbers of nests per unit length of coastline. Caution is required in comparing waterfront densities, however, as the indicated length of coastline can vary with the scale of maps or methods of measurement used in the survey (James G. King, personal communication, 1986). Robards and King (1966) surveyed 860 miles (1385 km) of coastline on Admiralty Island and adjacent small islands and reported that densities of active nests (nests containing eggs or young) averaged 0.53 per mile (0.33 per km) of coastline. They also surveyed 30 miles (48 km) of coastline in the Juneau area and 60 miles (97 km) of riverfront in the Chilkat Valley and found nest densities of 0.53 and 0.40 active nests per mile (0.33 and 0.25 per km), respectively (Robards and King 1966). Corr (1974) surveyed eagle nests on plots located within 40 miles (64 km) of Petersburg from 1967 to 1969. Density of active nests (containing eggs or young) averaged 0.21 per mile (0.13 per km). Collectively, active and inactive nests (without eggs or young) averaged 0.60 nests per mile (0.37 per km) of beach.

In 1969, the U.S. Fish and Wildlife Service initiated a program to locate bald eagle nests throughout southeast Alaska (Hodges and Robards 1982). These surveys occur annually from April to September, and usually concentrate on areas programmed for timber harvest or other management activity. As of 1982, 3,850 nests had been located. Data summarized for this period yielded

Table 2. Volumetric percentages of food items contained in the stomachs of 435 bald eagles collected primarily along the coast of southeast Alaska south of Juneau (Source: Kalmbach, E.R., R.H. Imler, and L.W. Arnold, 1964. The American eagles and their economic status, 1964. U.S. Dep. Interior, Fish and Wildlife Service, Washington, D.C. 35 pp.).

	Month				
Food item	Jan. (n=10)	Feb. (n=28)	Mar. (n=30)	Apr. (n=25)	May (n=98)
Fishes					
Salmonidae[1]	10.0				2.0
Gadidae[2]	28.8	44.2	23.3	5.7	22.0
Cataphracti[3]	20.0	13.7	14.4	30.2	6.1
Heterostomata[4]	22.0	15.9		21.6	11.4
Clupeidae[5]			10.0		9.0
other fish			10.0	12.2	19.5
Birds					
Anatidae[6]	19.2	3.6	8.7	22.3	2.2
other birds[7]	Trace	9.6	25.4	4.0	2.9
Mammals					6.1
Invertebrates[8]		4.8	1.5		8.2
Carrion[9]		8.2	6.7	4.0	10.6

[1] Salmon, trout.
[2] Pollack, cod.
[3] Sculpins, scorpionfishes, rockfishes.
[4] Flounders, halibut.
[5] Herrings, anchovies.
[6] Ducks, geese.
[7] Mainly auklets, murres, and other sea birds.
[8] Crustaceans and miscellaneous invertebrates.
[9] Remains considered to have been carrion included deer (*Odocoileus hemionus sitkensis*), harbor seal (*Phoca vitulina*), and northern sea lion (*Eumetopias jubata*). Fishes and other animals small enough to have been taken as prey were not counted as carrion, although they may have been dead when eaten.

average nest density, including both active and inactive nests, of 0.80 per mile (0.50 per km) of beach habitat. Highest densities, averaging 1.05 nest per mile (0.65 per km), were reported on Admiralty Island (Hodges and Robards 1982).

Nest densities have also been determined for bald eagles that nest along the inland river systems of southeast Alaska. In these situations nesting habitat consists of large, mature stands of cottonwood trees (*Populus trichocarpa*) that occur in the most stable portions of the river bottomland. A survey of the cottonwood stands along the mainland river systems of southeast Alaska located 191 bald eagle nests along 334 miles (541 km) of habitat surveyed (Hodges 1979). Overall nest density (including active and inactive nets) averaged 0.57 nest per mile (0.35 nest per km), with highest densities occurring along the Chilkat River (1.65 nest per mile [1.02 per km]) and the Taku River (1.15 nest per mile [0.71 per km]).

Hansen et al. (1984) reported breeding densities in the Chilkat Valley as the number of bald eagle breeding areas per mile of river. They considered a breeding area to be a site containing one or more nests, any of which might be used by a particular eagle pair but not by other pairs (Andrew J. Hansen, personal communication, 1986). The 89 breeding areas within the area were distributed at an average density of 0.61 per mile (0.38 per km). Most of these nests were located along the Chilkat River and its tributaries.

Productivity

Indicators used to assess bald eagle productivity include: (1) proportion of active nests (containing eggs or young) to total nests in an area; (2) average clutch size; (3) number of young produced per active nest; (4) survival rates of pre-fledgling young; and (5) the proportion of breeding adults to total adults (i.e., the proportion of adults that contribute to the reproductive effort of the population in a given year).

Month							
June (n=70)	July (n=59)	Aug. (n=64)	Sep. (n=23)	Oct. (n=11)	Nov. (n=11)	Dec. (n=6)	$\overline{X}$
11.8	24.1	35.8	85.0	25.4	9.1		16.9
16.7	10.5	5.2			9.1	33.3	16.6
8.0	11.0	6.5	Trace	3.8			9.4
14.4	17.4	5.6	1.8	1.8			9.3
1.4	2.3	4.7	0.2				2.3
18.5	8.0	13.0		27.3	9.1	16.7	11.2
2.1				5.3	52.7		9.7
4.3	6.4	2.5	2.6	9.1	9.1	33.3	9.1
4.2			4.3				1.2
2.2	3.9	0.6	1.8				2.0
16.4	16.4	26.1	4.3	27.3	10.9	16.7	12.3

Robards and King (1966) surveyed eagle nests at three southeast Alaska locations (Admiralty Island, the Juneau vicinity, and the Chilkat Valley) between 15 March and 7 July, 1966. They found mean activity rates (percent of total nests active) of 40 percent, 50 percent, and 46 percent, respectively, for the three areas. In the same study, helicopter checks were made of 72 nests on Admiralty Island to determine nest activity, clutch sizes, and survival rates. Checks conducted during incubation (9 May) found that 6 of the nests contained one egg, 63 contained 2 eggs, and 3 contained 3 eggs. Average clutch size was 1.96 eggs per nest. Later checks conducted on 7 June and 7 July found that 82 percent of the eggs had successfully hatched, and 72 percent had survived to fledgling stage. From 1967 to 1969, Corr (1974) conducted aerial surveys of eagle nests within 40 miles (64 km) of Petersburg. The mean number of eaglets per nest in June and July was 1.50, 1.65, and 1.53, respectively, in 1967, 1968, and 1969. No nests were observed to contain more than two eaglets.

Hansen et al. (1984) studied nesting eagles in the Chilkat Valley from 1979 to 1983, and reported activity rates (percent of breeding territories occupied by adult pairs) that ranged from 32 percent to 60 percent. The nests within these territories were checked in mid-August to determine nesting success. The percentage of active nests containing young averaged 32 percent from 1979 to 1983 (range: 15 to 61 percent). The mean number of young produced per productive nest during this period ranged from 1.22 to 1.52, with overall mean productivity of 1.32 young per productive nest.

A productivity study of nesting bald eagles in the Seymour Canal Eagle Management Area, Admiralty Island, has been underway since 1972 by the U.S. Fish and Wildlife Service in cooperation with the USDA Forest Service (Hodges 1982a). This area, which supports unusually high densities of nesting bald eagles, is managed as Wilderness under the Tongass Land Management Plan (USDA Forest Service 1979). Surveys are conducted annually by helicopter during the last 2 weeks of June to determine nesting activity rates and numbers of eggs or young produced per nest. Of active nests counted from 1972 to 1981, 43 percent contained 1 egg or young, 55 percent contained 2 eggs or young, and 1.3 percent contained 3 eggs or young (Hodges 1982a). From 1972 to 1986, the number of eggs and young per active nest has ranged from 1.12 in 1979 to 1.83 in 1973, with a mean of 1.46 per nest (U.S. Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data). Survey results suggest that productivity during the last 7 years has been generally lower than levels recorded prior to 1979 (Table 3).

Limited data have been collected in the Seymour Canal Eagle Management Area to assess survival rates of eggs and pre-fledgling young. Average survival rate of pre-fledgling young in 10 active nests monitored in 1972 was 0.81 from 8 June to 21 June. In 1979, young in 17 active nests had a mean survival rate of 0.70 from 21 June to 6 August, (Hodges 1982a).

Table 3. Number of active nests, number of eggs and young, and mean number of eggs and young per active nest in the Seymour Canal Eagle Management Area from 1972 to 1986 (Source: U.S. Dep. Interior, Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska. Unpublished data).

Year	Active nests	Eggs and young	Eggs and young per active nest
1972	25	39	1.56
1973	24	44	1.83
1974	21	33	1.57
1975	28	38	1.36
1976	29	42	1.45
1977	38	58	1.66
1978	39	68	1.74
1979	17	19	1.12
1980	17	22	1.29
1981	20	28	1.25
1982	18	28	1.56
1983	9	12	1.33
1984	20	22	1.29
1985	15	17	1.42
1986	18	26	1.44

In selected years (1970-72 and 1979), the bald eagle nest surveys of the U.S. Fish and Wildlife Service (Hodges and Robards 1982) collected information to estimate the proportion of breeding to nonbreeding adults. These data, analyzed by Hansen and Hodges (1985), suggest that a significant portion of the adult population in any year does not contribute to the reproductive effort of the population, providing major evidence for a nonbreeding surplus. The percentage of adult eagles determined to be breeders (i.e., associated with active nests) was 84 percent, 38 percent, and 43 percent, respectively, for the 1970, 1971, and 1972 seasons. In 1979, only 14 percent of adult eagles were classified as breeders. These data indicate that many mature bald eagles do not breed annually, and that the extent of non-breeding is variable among years. The high proportion of inactive nests suggests that breeding is limited by factors other than nest site availability.

Population Regulation

The high occurrence of nonbreeding in bald eagles of southeast Alaska has been investigated by Hansen et al. (1986) in the Chilkat Valley. The study tested three hypotheses for the limited breeding observed, including: (1) limitation by chemical toxins; (2) limitation by habitat; and (3) food limitation. Failure of chemical analyses to find abnormal levels of chemical residues in southeast Alaska bald eagles and their eggs led to rejection of the first hypothesis. Specific habitat attributes were found to be related to selection of habitat by breeding bald eagles but not to survival of eggs or chicks. Experimental manipulation of the food source gave greatest support for the food limitation hypothesis. Food proximity and availability were found to have a positive relationship with activity rate of nests, onset (date) of laying, and nesting success. From this study, Hansen et al. (1986) concluded that: (1) food abundance in spring strongly influences where, when, or if eagles lay eggs; (2) habitat quality is important for selection of breeding areas, partially because of its influence on foraging success; and (3) food supplies during incubation and rearing regulate offspring survival.

The surplus of nonbreeding bald eagles reported by Hansen and Hodges (1985) may suggest a population that is at saturation with regard to suitable breeding sites having adequate food resources. As

suggested by the experimental evidence of Hansen et al. (1986), these resources may determine the number of bald eagles that can successfully breed in any given year. Alternatively, the depresssed reproduction of recent years may be indicative of some change in food supply or other environmental factors that may, in turn, be related to human activities (Hansen and Hodges 1985). The phenomenon of nonbreeding would need further study to determine if it is an intrinsic characteristic of the bald eagle population of southeast Alaska, or whether it is indicative of recent environmental change (Hansen and Hodges 1985).

Breeding Behavior

Bald eagles in southeast Alaska construct their nest platforms of sticks up to 4 feet (1.2 m) long and 2 inches (5.1 cm) wide (Robards and King 1966). Mosses are used to line the nest, along with lesser amounts of grasses, twigs, seaweed, and other debris (Steven L. Cain, personal communication, 1986). Bald eagles tend to use the same nest year after year, making repairs as needed. The data of Robards and Hodges (1976) suggest a spacing mechanism whereby pairs avoid selecting nests closer than 0.6 mile (1.0 km) to another active nest. Presence of more than one nest within a breeding area is not uncommon. Of 89 breeding areas identified in the Chilkat Valley, 62 appeared to have 1 nest, 25 had 2 nests, and 2 had 3 nests (Hansen et al. 1984). These alternate nests may be used if the active nest is disturbed or destroyed. Pairs may use alternate nests even when the primary nest is available, however, and this suggests that alternate nests may serve additional functions. Suggested functions of alternate nests include reduced susceptibility to nest parasites or predators, and reduced impacts of nesting on individual nest trees and adjacent resources (Stalmaster et al. 1985).

Breeding activities in southeast Alaska begin as early as February, and involve establishment and defense of the breeding area (Fig. 2). Robards and King (1966) monitored 72 nesting pairs of bald eagles on Admiralty Island and vicinity, and found that all were incubating by 9 May. During the last 2 weeks of June, when the productivity surveys are flown in the Seymour Canal Eagle Management Area of Admiralty Island, about 92 percent of the nests have been found to contain downy young, with the remaining 8 percent containing incubating eggs (Hodges 1982a). These observations suggest that in southeast Alaska egg-laying peaks around the third week of April, followed by a peak in hatching around the last week of May.

Cain (1985) used time-lapse photography to study nesting behavior associated with three bald eagle nests near Juneau, and found that male and female bald eagles share nesting duties to a greater extent than many other raptors. At least one adult of

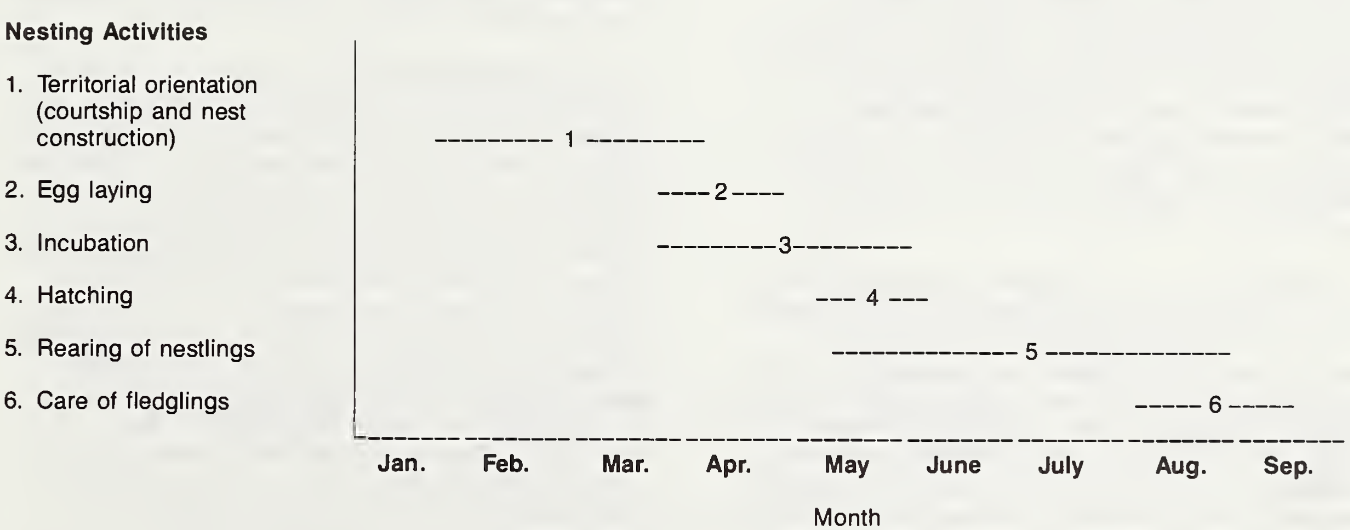

Fig. 2. Sequence of bald eagle nesting activities in Alaska (Source: U.S. Fish and Wildlife Service, Raptor Management Studies, Juneau, Alaska).

a pair remained on the nest almost continuously during incubation, and nest attendance remained high during the first few weeks of hatching. The pairs were observed to incubate approximately 94 percent of the daylight hours, with females averaging 52 percent and males 42 percent. Brooding time averaged 79 percent of the daylight hours for the first 10 days following hatching, of which 56 percent was by females and 23 percent by males. Brooding declined as the young grew older, and averaged only 6 percent of the daylight hours by the sixth week after hatching. Both males and females brought prey to the nest, although most (81 to 91 percent) of all feedings were conducted by females (Cain 1985).

Newly hatched young are covered with white or gray down that is replaced by thicker down at age 2 to 3 weeks (Evans 1982). First feathers appear at 4 to 5 weeks, and the young fledge at age 10 to 12 weeks. In southeast Alaska, fledging peaks in mid to late August (Fig. 2). Although Brown and Amadon (1968) reported that young bald eagles typically are fed by their parents for several weeks after fledging, this dependence has not been observed for bald eagles in the Chilkat Valley (Andrew J. Hansen, personal communication, 1986). Most bald eagles do not reach sexual maturity until they are at least 5 to 6 years old (Evans 1982).

Responses to Disturbance

Bald eagles are vulnerable to disturbance both in their nesting habitats and in seasonal concentration areas. Whether a given event is significant or not depends upon the severity of the disturbance and the response of the bald eagle involved. Because bald eagles vary considerably in their response to human activity, however, it is difficult to predict the effects of a given type of human disturbance on individual eagles (Stalmaster et al. 1985). Disturbance, although difficult to measure, is an important management concern if it results in decreased probability of survival or decreased productivity.

The vast majority of coastal southeast Alaska is without permanent human habitation and residential or commercial developments. Most potential disturbances to bald eagles are associated with road construction, timber harvest, and recreational use of National Forest lands and surrounding waters. Specific activities that bald eagles may be exposed to include boat traffic, car traffic, low-flying airplanes and helicopters, foot traffic, truck and other heavy equipment traffic, surface and subsurface blasting, firearm discharge, and logging. In general these activities, except logging and frequent use of certain roadways, create sporadic rather than prolonged disturbance.

Disturbance in Seasonal Concentration Areas. Disturbance is an important factor in areas where bald eagles concentrate seasonally. At such locations, it is important that bald eagles have access to the food source that attracted them there, and sufficient time to feed. The major effects of disturbance at feeding grounds are to deny the birds access to food, restrict the time available for feeding, and cause energy to be expended in avoidance flights. Stalmaster and Newman (1978) studied the effects of human activity on bald eagles that congregate along the Nooksack River, in northwest Washington, to feed on spawned-out salmon. The study revealed a negative relationship between human activity and the numbers of bald eagles using portions of the winter feeding area. The study provided evidence that human activity prevented full and effective use of available feeding sites, and reduced the feeding success of eagles exposed to disturbance.

Hansen et al. (1984) observed that the nature of disturbance along the Chilkat River of southeast Alaska influenced how many bald eagles were displaced from the feeding ground, how far they moved, and the time required for the birds to return. The typical response of bald eagles to a disturbance of low intensity and short duration, such as a small group of people passing by, was a temporary shift of location to another portion of the feeding ground. When subjected to more intense and/or prolonged disturbances, most bald eagles left the feeding ground to seek refuge in conifer roosting areas. These disturbances included airplanes landing on gravel bars, low-flying helicopters, noisy or sustained boat traffic, and frequent human presence on gravel bars (Hansen et al. 1984).

The setting where the disturbance occurs may affect the response of bald eagles. Along the Nooksack River in northwest Washington, bald eagles in open feeding areas were the most reactive to disturbance (Stalmaster and Newman 1978). The birds were more tolerant of disturbance (i.e., had shorter flushing distances) when feeding areas were partially screened by vegetation. Knight (1981) reported that bald eagles feeding on river bars and banks were more prone to flush than eagles perched in trees along the river. Knight and Knight (1984) used a canoe to approach bald eagles feeding along the Nooksack and Skagit Rivers of northwest Washington. They found that birds feeding on the ground flushed more readily when in groups than when solitary. In the Chilkat Valley, Hansen et al. (1984) reported highest tolerance levels to disturbance along roadways and suggested that bald eagles may have become habituated to activity in these settings.

Disturbance in Breeding Habitats. Some information on the behavioral response of bald eagles to disturbance, and related effects on nesting success, is available from geographic areas outside of southeast Alaska. Fraser et al. (1985) subjected nesting bald eagles on the Chippewa National Forest to experimental disturbance, and found great variation in flushing distance. These experiments did not provide evidence that the birds habituated to repeated disturbance; rather, flushing distance increased with successive intrusions into the nest area.

Vulnerability of bald eagles to disturbance is believed to vary during the stages of the breeding cycle. Vulnerability is believed to be highest during the period of territory establishment and mating, when nest site tenacity is low and pairs may abort their nesting attempt or desert the site (Stalmaster et al. 1985). Egg laying and incubation have been suggested as the most critical periods by Stalmaster et al. (1985), who cite the findings by Fraser (1981) of a negative relationship between disturbance and production of young. Normally during incubation and into the early nestling period, one parent or the other is on the nest almost continuously (Cain 1985). If disturbed, the adults may leave the nest and expose the eggs or hatchlings to weather or predators.

Risks associated with disturbance decline as the nestlings develop and spend increasing amounts of time alone at the nest (Mathisen 1968, Cain 1985). Although unsubstantiated by research, there is concern that risk may again increase as the nestlings near fledging. This concern is based on observations in southeast Alaska of young eagles jumping out of the nest when approached by helicopters during nest surveys (John I. Hodges, Jr., and Steven L. Cain, personal communication, 1986). Although disturbance and its effects have not been quantitatively evaluated in southeast Alaska, the relationships just described may be used to hypothesize the relative vulnerability of bald eagles to disturbance during the different stages of the nesting cycle (Fig. 3).

Studies conducted outside southeast Alaska have attempted to measure how sustained human presence within eagle habitat affects nesting activity and nest site selection. Mathisen (1968) evaluated nesting activity of bald eagles on the Chippewa National Forest, Minnesota, in relation to the wilderness character of their habitat (i.e., the degree of isolation from human presence). Rates of nest occupancy and nesting success were not

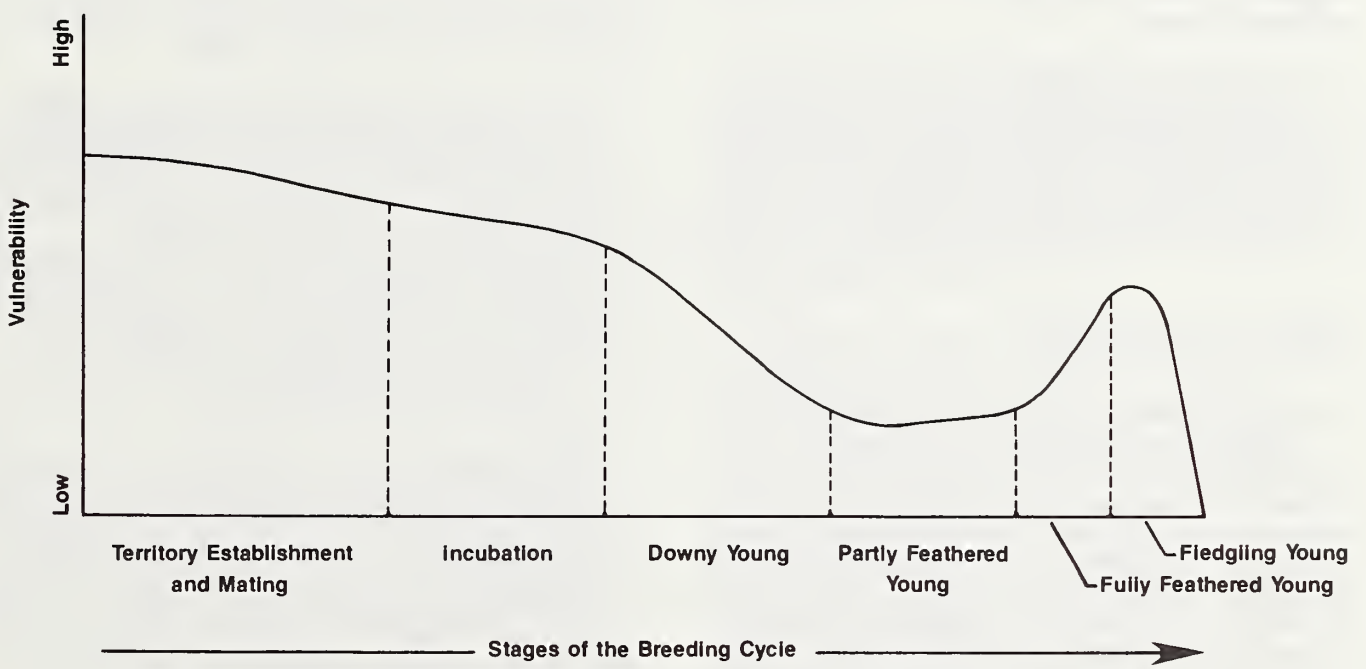

Fig. 3. Hypothetical changes in the vulnerability of bald eagles in southeast Alaska during the breeding cycle.

significantly different between areas of high, moderate, and low wilderness character. The author concluded that most human activity on the Chippewa National Forest, including recreational use and timber harvest, occurred late enough in the breeding cycle that vulnerability of bald eagles was relatively low. In a later study on the Chippewa National Forest, Fraser et al. (1985) measured the distance of bald eagle nests to water and found smaller distances in undeveloped areas than in areas having residential developments. The same study found that bald eagle nests were located farther from houses than were a random sample of points along the shoreline. These findings suggest that bald eagles are avoiding human settlements in their selection of sites for new nests.

Efforts to relate human activities to reproductive success of bald eagles are generally inconclusive. Mathisen (1968) found no evidence that nesting success of bald eagles differed with degree of isolation from human activities on the Chippewa National Forest of Minnesota. Fraser et al. (1985) evaluated human activities within 1640 feet (500 m) of successful and unsuccessful nests on the Chippewa National Forest. This analysis provided no evidence of a relationship between nest success and exposure to human activities. In contrast, Grub (1980) found that successful nests in western Washington, on the average, were located farther from developments than were unsuccessful nests. These findings suggest a possible negative effect of development on bald eagle nesting.

No comparable studies have been conducted in southeast Alaska, although Corr (1974) noted that bald eagles made only limited use of shoreline areas that received heavy use by humans. The main disturbance in these cases was offshore boat traffic, including commercial and pleasure craft.

Habitat Relationships

Habitat of Seasonal Concentration Areas

Important characteristics of bald eagle concentration areas are: (1) an abundant and available food source; (2) day perches for hunting and resting; and (3) suitable roosting habitat. Special conditions in the Chilkat Valley account for its importance as a fall and winter feeding area. The Chilkat River is influenced by upwellings of relatively warm water from subsurface aquifers (Bishop 1980, cited in Hansen et al. 1984). This prevents portions of the river from freezing, and creates favorable spawning habitat for late runs of chum and coho salmon.

Bald eagles require suitable roosting habitat in association with their feeding areas. Roosting habitat provides protective sites that reduce exposure to wind, rain, and low air temperatures, and that reduce loss of long-wave radiation. These conditions enable bald eagles to maintain body temperature and to reduce energy expenditure and loss (Stalmaster et al. 1985). Hansen et al. (1984) observed that most night roosting in the Chilkat Valley occurred in stands of cottonwood and conifer trees. Although cottonwoods were extensively used until mid-fall, by late fall and winter bald eagles had shifted to communal night roosts within specific stands of hemlock and spruce that were topographically shielded from wind. Bald eagles also sought refuge in conifer stands during winter storms and when disturbed by humans.

Eagles that concentrate around the mouth of the Stikine River in spring do not appear to use well-defined night roosts. Rather, they occur dispersed throughout the timbered slopes that surround the feeding area (USDA Forest Service, Tongass National Forest, Petersburg, Alaska. Unpublished data).

Breeding Habitat

Inland Nesting. The mainland of southeast Alaska is served by 12 major river systems and several minor river systems that are generally of glacial origin and that flow in braided patterns over wide gravel beds on the valley floors. The more stable portions of these river bottomlands support stands of large, mature cottonwood trees that are used as nesting habitat by bald eagles (Hodges 1979).

Hodges (1979) found nest densities to be highly variable among the rivers surveyed in southeast Alaska, and postulated that use of river habitats for nesting may also fluctuate among years in response to food abundance and weather conditions. Altogether, the large mainland river systems of southeast Alaska were found to support an estimated 200 bald eagle nests (Hodges 1979). Occasional nests also occur along major streams and lakes of the larger islands, most notably on Prince of Wales Island (Hodges and Robards 1982).

Coastal Nesting. By far, the majority of bald eagles in southeast Alaska nest in coniferous forest habitats along the coastline and associated saltwater inlets. A wealth of information on nesting habitat has been gathered through the nest surveys of the U.S. Fish and Wildlife Service. Robards and Hodges (1976) and Hodges and Robards (1982) have summarized these data, which provide a comprehensive picture of the habitats and nest sites selected by breeding eagles in coastal southeast Alaska.

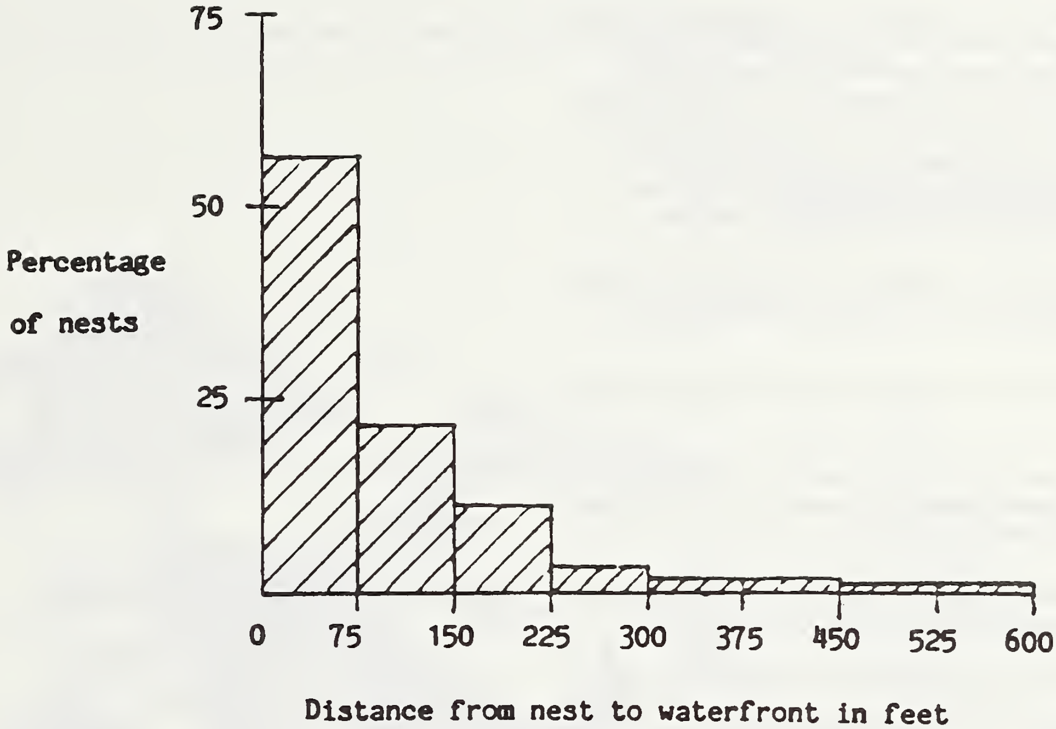

Fig. 4. Frequency distribution of distances from nest to waterfront for 3,850 bald eagle nests in coastal southeast Alaska (Source: Hodges and Robards, 1982).

Bald eagles prefer to nest adjacent to the coast, where they forage for fish, waterbirds, marine invertebrates, and drifting carrion. Of 3,850 nests surveyed by Hodges and Robards (1982), 92 percent occurred within 300 feet (91 m) of the shoreline, and average distance from nest to shoreline was 120 feet (37 m) (Fig. 4). Not all types of shoreline appeared equally acceptable to nesting bald eagles. The majority of nests examined (55 percent) were located along inland seas or broad channels. Nesting along saltwater bays was also common (31 percent), whereas brackish lagoons, open seas situations, and narrow saltwater channels without tidal currents were used less frequently. Nests commonly occurred on prominent points of land, small islands, narrow passages with tidal currents, and shorelines exposed to large bodies of water, especially those facing into prevailing winds. These situations may provide best opportunities for foraging over open water and on tidal flats.

Almost all nesting along coastal southeast Alaska occurs in old-growth stands located within a well-forested landscape. A survey of nesting bald eagles along the coast of British Columbia included areas that had been extensively logged (Hodges et al. 1984). Presence of remnant old-growth trees appeared to be an important factor associated with nesting in clearcuts, even-aged second growth, and other disturbed areas. The data suggested that disturbed areas lacking remnant old-growth trees were avoided (Hodges et al. 1984).

In coastal southeast Alaska, Sitka spruce comprised 78 percent of 3,850 nest sites evaluated by Hodges and Robards (1982). Spruce trees are usually taller and have a stronger top and branches than western hemlock, which comprised 20 percent of the nest sites. Western redcedar (*Thuja plicata*) was used in only 2 percent of the cases observed. Large, old trees are most commonly selected for nesting. Nest trees examined by Hodges and Robards (1982) averaged 97 feet (30 m) in height and 3.6 feet (1.1 m) in diameter. These measurements suggest that typical nest trees are at least 400 or 500 years old.

Tree condition appears to be a significant factor of nest site selection. Of the 3,850 nests examined by Hodges and Robards (1982), only 6 percent were

in dead trees. Trees selected by nesting bald eagles most commonly have a top that is bushy, broken, or deformed. Such tops are more likely to provide strong support for the massive nests of bald eagles. The physical characteristics of trees selected for nesting provide a basis for classifying nests, as follows. Values are the percentages of 3,850 southeast Alaska nests that were in each category.

1. Nest supported by upper branches which formed a cradling matrix after the tree top was damaged, 19 percent (Fig. 5A).

2. Nest located in a bushy tree top, 21 percent (Fig. 5B).

3. Nest located in a slender tree top, usually well below the upper crown, supported by strong, lateral limbs, 14 percent (Fig. 5C).

4. Nest located in upper whorl of branches with the dead top above the nest, 17 percent (Fig. 5D).

5. Nest located in a dead tree, 6 percent (Fig. 5E).

6. Nest located in a tree with a deformed top, often in the crotch of a U-shaped branch, 19 percent (Fig. 5F).

7. Nest located in a tree with multiple tops, 14 percent (Fig. 5G).

Nests observed during the annual productivity surveys in the Seymour Canal Eagle Management Area suggest that the number of new nests built each year approximates the number lost each year (Hodges 1982a). Annual rate of nest loss in Seymour Canal is about 5 percent, which implies an average nest life of 20 years. Assuming this area is typical of southeast Alaska, about 50 percent of the original nests of a given area will be lost after 13 years. The main causes of loss are nests blowing out of trees and nest trees succumbing to windthrow (Hodges 1982a).

Perching sites are an important component of bald eagle nesting habitat. Bald eagles perch on tall trees and snags to scan the water and shore for food. They also use these vantage points to protect their nests from avian predators. Tall trees having a clear view of the nest and surrounding water provide the most valuable perching sites. Other functions of perch trees have been suggested. These include: (1) sites for consuming prey; (2) sites from which to display to attract potential mates; (3) conspicuous posts from which territory occupation may be signaled (Stalmaster et al. 1985).

Fig. 5. Seven categories of nest trees used by bald eagles in southeast Alaska.

Figure. 5(A). Nest supported by upper branches which formed a cradling matrix after the treetop was damaged.

Figure. 5(B). Nest located in bushy treetop.

Fig. 5, continued. Seven categories of nest trees used by bald eagles in southeast Alaska.

Figure 5(C). Nest located in a bushy treetop, usually well below the upper crown, supported by strong, lateral limbs.

Figure 5(D). Nest located in upper whorl of branches with the dead top above the nest.

Fig. 5, continued. Seven categories of nest trees used by bald eagles in southeast Alaska.

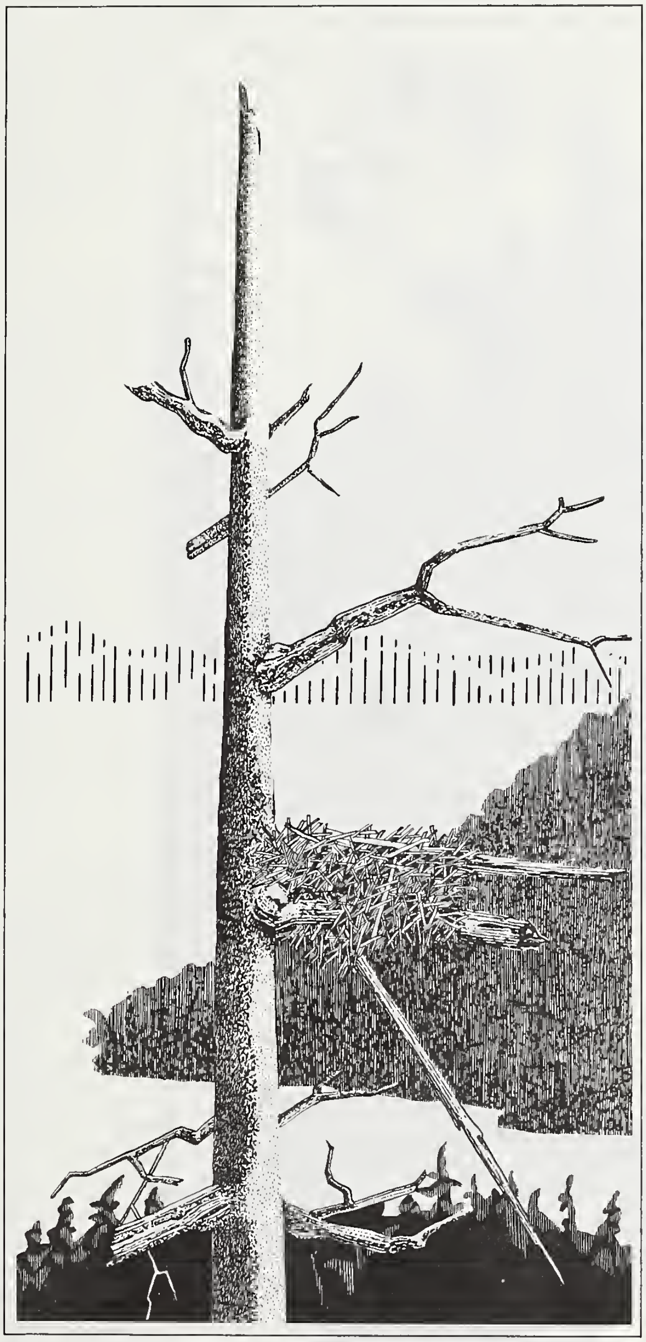

Figure 5(E), (above). Nest located in a dead tree.

Figure 5(F), (right). Nest located in a tree with a deformed top, often in the crotch of a U-shaped branch.

Fig. 5, continued. Seven categories of nest trees used by bald eagles in southeast Alaska.

Figure 5(G). Nest located in a tree with multiple tops.

Management of Breeding Habitat

Habitat Protection. A major habitat management concern for the bald eagle in southeast Alaska is protection of nests and associated nesting habitat from loss or disturbance. On National Forest lands in Alaska, protection measures for bald eagles and their nesting habitats are prescribed in a Memorandum of Understanding between the USDA Forest Service and the U.S. Fish and Wildlife Service. Provisions contained in this Memorandum have been consistently applied to State and some private lands of southeast Alaska, as well as National Forest lands.

A version of the buffer zone concept described by Mathisen et al. (1977) is applied in the Memorandum to protect breeding habitat of bald eagles on National Forest lands in southeast Alaska. A buffer zone of 330 feet (100 m) radius is established around all active and inactive eagle nests. The Memorandum provides for exclusion of all land-use activity within this zone. In instances where scheduling of a land-use activity within the buffer zone is unavoidable, the Fish and Wildlife Service is notified by the Forest Service. Following a joint field inspection, the two agencies may agree to proceed with development inside the buffer zone if the risk of disturbance to nesting bald eagles is considered minimal. This often involves scheduling activities to avoid the nesting season. The nest buffer zone is maintained even if the nest becomes unsuitable for use, thereby ensuring protection of known nesting habitat.

The 330-foot buffer zone used in southeast Alaska is less restrictive than policy applied on many National Forests in the lower 48 states. Most applications of the concept include at least two levels of protection (Stalmaster et al. 1985). A primary zone of 330 feet (100 m) radius is established around nest trees to restrict all human activity, development, and logging throughout the year. A secondary buffer zone of 660 feet (200 m) radius may be established around active nests to provide additional protection during the breeding season. This basic system has been modified in some areas to offer even greater assurance and flexibility in the protection of nesting habitat of bald eagles. Mathisen et al. (1977) described a system on the Chippewa National Forest, Minnesota, that includes the primary and secondary buffer zones plus two more buffer zone categories offering additional spatial and temporal restrictions. Under this system, the most appropriate buffer zone prescription for a given site is identified in a detailed management plan prepared for each bald eagle nest (Mathisen et al. 1977).

The 330-foot buffer zone has been in effect in southeast Alaska since 1969. To evaluate the effectiveness of this policy, Hodges (1982b) determined the status and condition of nest trees and associated buffer zones before and after the occurrence of logging within 1.0 mile (1.6 km) of the nest. The evaluation provided no evidence that logging and associated developments (roads, rock quarries, camps, log storage sites) had caused a significant decline in nesting activity of bald eagles. The major threat to bald eagle productivity was the high incidence of windthrow observed in association with cutover areas. The integrity of the buffer zone is at greatest risk where clearcutting extends up to the perimeter of the buffer zone. Hodges (1982b) estimated that the area contained within these buffer zones will be reduced by 17 percent, on the average, 5 years after the adjacent timber has been clearcut.

The evaluations of Hodges (1982b) suggest that a larger buffer zone may be needed to ensure adequate protection of eagle nest trees against windthrow. Based on his study in the Petersburg area, Corr (1974) recommended that a buffer zone of 660 feet (200 m) radius be used in areas scheduled for timber harvest.

The Memorandum of Understanding between the Fish and Wildlife Service and the Forest Service recognizes the importance of perch trees to bald eagles, and contains provisions to maintain this habitat component in coastal southeast Alaska. The Memorandum recommends that a continuous fringe of mature trees, at least one tree in width, be maintained along the coastline to meet the perching needs of bald eagles. As a minimum standard, one perch tree within 120 feet (37 m) of the high tideline must be retained within every 300 feet (91 m) of shoreline. When windfirm trees over 24 inches (61 cm) in diameter at breast height are not available, a group of the largest available windfirm trees must be retained.

Habitat Evaluation and Planning. Successful planning for the bald eagle on National Forest lands requires evaluation of the amounts and quality of bald eagle habitat that will result from the management alternatives considered in a given land-use plan. To conduct these evaluations, managers must be able to: (1) identify key areas of habitat for the bald eagle; (2) evaluate existing quality of habitat for bald eagles; and (3) predict changes in habitat quality that will result from management activities considered in the plan.

Habitat Suitability Index (HSI) models have been successfully applied to these types of evaluations in land-use planning (Schamberger and Farmer 1978, Rhodes et al. 1983, Urich and Graham 1983). These models utilize information available in the literature on the habitat relationships of a species to develop

an index value between 0.0 and 1.0 that is assumed to be linearly related to carrying capacity (USDI Fish and Wildlife Service 1981). The value 0.0 represents unsuitable habitat, while 1.0 represents optimum habitat for the species.

Part II of this document presents a Habitat Suitability Index model for breeding bald eagles in southeast Alaska. The model may be used to identify key areas of bald eagle habitat for special consideration in planning and scheduling of land-use activities. Applications of the model include assessment of existing habitat condition of an area, and evaluation of the area's potential to support breeding bald eagles over time.

Part II. Habitat Suitability Index Model for Breeding Bald Eagles in Southeast Alaska

Model Applicability

This model has been developed for application along coastal habitats in southeast Alaska, where the majority of nesting by bald eagles occurs. It is not applicable for evaluating bald eagle nesting habitat along river valleys and inland lakes of southeast Alaska. The general relationships modeled will apply to other areas but specific parameters (e.g., forest communities, distances) may have to be modified to reflect local habitat conditions. Only those variables for which information is available in Forest Service data bases are included in this model to ensure its utility through all phases of project planning and implementation. This model evaluates only the nesting habitat of the bald eagle. Although characteristics of habitat selected by bald eagles during the winter have been documented through several studies in the lower 48 United States, relatively little is known of the winter movements and habitats of bald eagles in southeast Alaska. Extrapolation of the results without collaborative evidence from southeast Alaska is not appropriate. Use of habitats by nonbreeders in summer is poorly known and is not considered here.

Model Description

Variable 1: Plant Association or Forest Type

Sitka spruce trees typically dominate the old-growth forests of southeast Alaska. These trees provide the structure preferred by bald eagles for nest placement. Nearly 80 percent of 3,850 nest trees examined in southeast Alaska were Sitka spruce (Hodges and Robards 1982). Although approximately 20 percent of nest trees were western hemlock, this species is not preferred because it is generally shorter than Sitka spruce, is less persistent, and the terminal branching is much finer (Grubb 1976). Western redcedar, found throughout southern southeast Alaska, is rarely used as a nest tree because of its fine branching structure.

The value of a site for bald eagles is, therefore, directly related to forest structure and composition. Sites with tall, well-developed canopy structure and a high percentage of Sitka spruce in the overstory will be preferred by bald eagles (Hodges and Robards 1982). These conditions are largely a function of the plant association (potential climax plant community) of a site (Martin et al. 1985). The plant associations of southeast Alaska may be grouped relative to their importance to bald eagles in terms of canopy development, species composition, and height of trees (Table 4). These relationships may then be used to represent the value to bald eagles of different forest stands (Fig. 6) (Variable 1_A:$V1_A$). These relationships may also be applied to forest type, as described by the dominant species in the overstory, when information on plant associations is not available (Fig. 7) ($V1_B$).

Table 4. Plant associations of southeast Alaska grouped by their suitability as nesting habitat for bald eagles.[1]

Plant Association Group 1

Sitka spruce/blueberry/devil's club
Sitka spruce/devil's club
Sitka spruce/alder
Sitka spruce/blueberry

Plant Association Group 2

Sitka spruce/devil's club/skunk cabbage
Sitka spruce/Pacific reedgrass
Western hemlock/blueberry/devil's club
Western hemlock/blueberry/spinulose shield-fern
Western hemlock/devil's club

Plant Association Group 3

Western hemlock/blueberry
Western hemlock/blueberry/skunk cabbage
Western hemlock/blueberry/devil's club
Western hemlock/devil's club/skunk cabbage
Western hemlock/yellow cedar/blueberry
Western hemlock/yellow cedar/blueberry/skunk cabbage
Western hemlock/western redcedar/blueberry
Western hemlock/western redcedar/blueberry/skunk cabbage

Plant Association Group 4

Mixed conifer/blueberry/skunk cabbage
Mixed conifer/blueberry
Mixed conifer/skunk cabbage/lady fern
Mountain hemlock/blueberry
Mountain hemlock/blueberry/copper bush
Mountain hemlock/blueberry/false hellebore

Plant Association Group 5

Mixed conifer/blueberry/deer cabbage
Mountain hemlock/blueberry/mertens cassiope

[1] Source: Martin, J.R., W.W. Brady, and J.M. Downs. 1985. Preliminary forest plant associations (habitat types) of southeast Alaska: Chatham Area, Tongass National Forest (draft). U.S. Dep. Agriculture, For. Serv., Tongass National Forest. Sitka, Alaska. 91 pp.

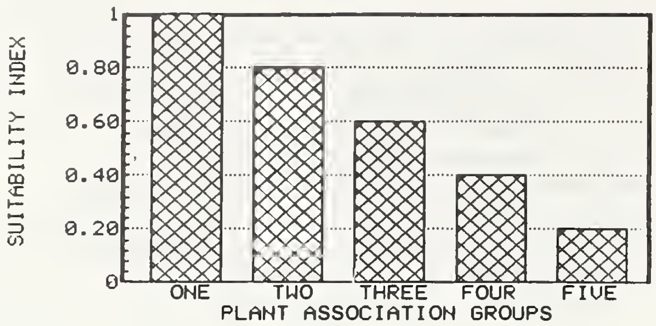

Fig. 6. Suitability of plant associations in southeast Alaska as nesting habitat for bald eagles. Groups of plant associations are displayed in Table 4.

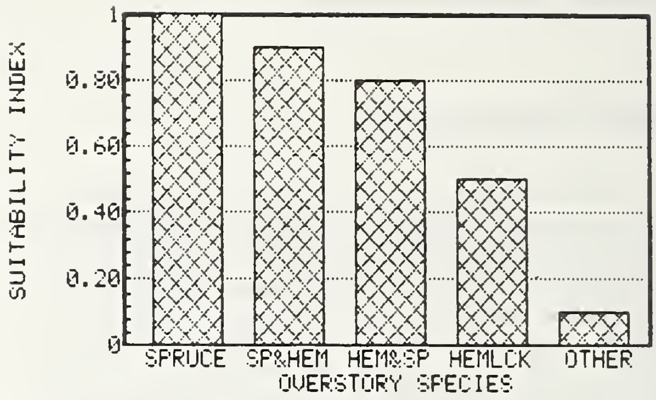

Fig. 7. Suitability of forest types in southeast Alaska as nesting habitat for bald eagles.

Variable 2: Stand Age Class

The average age of nest trees in southeast Alaska exceeds 400 years (Robards and Hodges 1976). Bald eagles in southeast Alaska prefer to nest in continuous stands of old growth rather than in narrow leave strips of old-growth trees. Nests of bald eagles have not been found in second-growth trees in southeast Alaska. These relationships indicate a preference by bald eagles for stands of old-growth timber and avoidance of second-growth stands less than 200 years old (Robards and Hodges 1976) (Fig. 8) (V_2).

Variable 3: Distance to Water

Bald eagles of southeast Alaska have a strong propensity to nest close to salt water. Corr (1974) found a mean distance of the nest tree to shore to be 100 feet (33 m) near Petersburg. Hodges and Robards (1982) reported that the average distance of nests to the waterfront throughout southeast Alaska was 120 feet (37 m), with 92 percent of the nest trees within 300 feet (91 m) and 98 percent within 600 feet (183 m) of the shoreline. Therefore, as distance from the shoreline increases, the value of the habitat for bald eagles decreases dramatically (Fig. 9) (V_3).

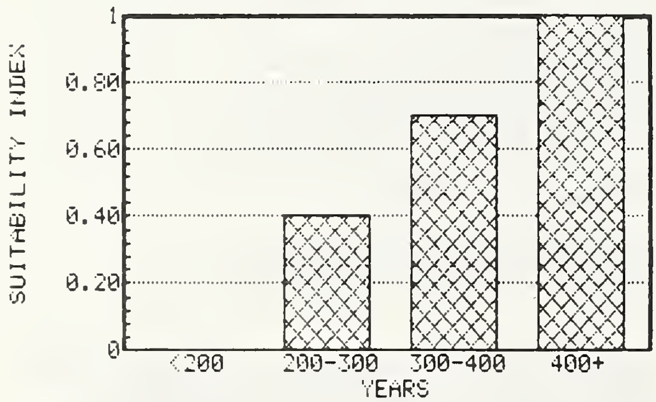

Fig. 8. Suitability of stand age classes as nesting habitat for bald eagles in southeast Alaska.

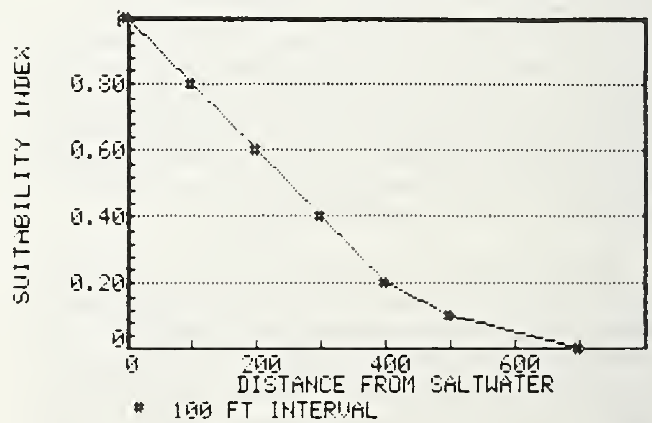

Fig. 9. Suitability of sites as nesting habitat for bald eagles in southeast Alaska in relation to distance from salt water.

Variable 4: Foraging Site Conditions

The large foraging areas provided by inland seas or broad channels are preferred by bald eagles, with nearly 55 percent of all nests observed in southeast Alaska occurring adjacent to such areas (Robards and Hodges 1976). Nearly 30 percent of all nests observed were located on saltwater bays and 12 percent on narrow saltwater channels. Heads of bays are often avoided (Robards and King 1966). The suitability of such sites as habitat for bald eagles was estimated based on these factors (Fig. 10) (V_4).

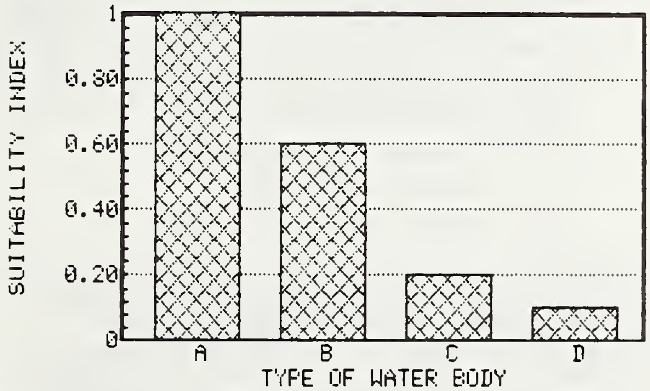

Fig. 10. Suitability of sites as bald eagle habitat in southeast Alaska in relation to foraging site conditions provided by: (A) inland seas or broad channels; (B) open saltwater bays; (C) narrow passages with tidal currents; and (D) heads of bays.

Variable 5: Shoreline Conditions

Broken shorelines or clusters of small islands provide higher quality habitat for bald eagles than continuous forested shoreline; steep-walled unforested channels, such as fiords, provide little habitat (Fig. 11) (V_5).

Variable 6: Stream Channel Type

Bald eagles in southeast Alaska utilize a significant amount of salmon as food (Imler and Kalmbach 1955; Ofelt 1975). Streams that attract large numbers of spawning salmon may enhance the suitability of adjacent sites as habitat for bald eagles. The potential productivity of a stream for salmon may be classified by channel type (USDA Forest Service, Tongass National Forest, Ketchikan, Alaska. Unpublished data) (Table 5). The average distance between nests in southeast Alaska is 1.2 mile (2.0 km), indicating that the average area associated with each bald eagle nest has a radius of 0.6 mile (1.0 km). An evaluation of the streams, by channel type, within 1 km of the site to be analyzed, will provide an indication of the availability of food in the area (Fig. 12) (V_6).

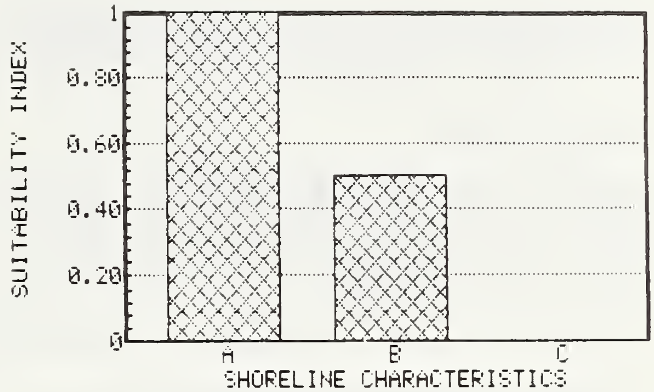

Fig. 11. Suitability of sites in southeast Alaska as bald eagle habitat in relation to shoreline conditions associated with: (A) broken shorelines or clusters of small islands; (B) continuous forested shorelines; and (C) steep-walled, unforested channels such as fiords.

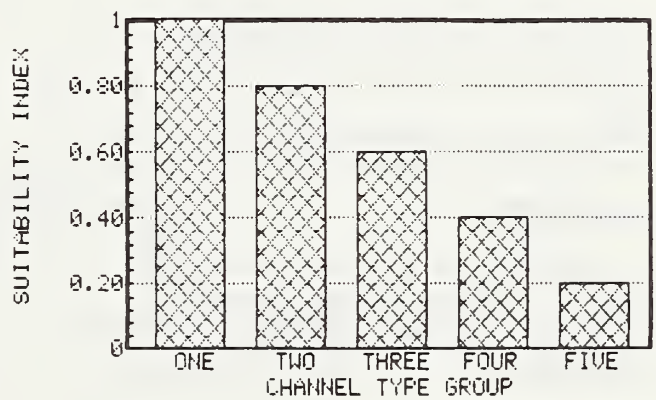

Fig. 12. Suitability of sites in southeast Alaska as bald eagle habitat for nesting bald eagles in relation to channel type of streams within 0.6 mile of the nest. Groups of channel types are displayed in Table 5.

Table 5. Stream channel types of southeast Alaska grouped by their potential to support runs of spawning fish as a food source for bald eagles.[1]

Channel Type Group 1

Low gradient, lower valley forest channel (C1)
Low gradient, incised lower valley muskeg channel (C2)
Broad, low gradient, lower valley forest channel (C3)
Large estuarine channel (E1)
Glacial estuarine channel (E3)

Channel Type Group 2

Low gradient, lowland forest channel (B1)
Broad, high energy lower valley channel (C4)
Low gradient, narrow valley forest channel (C5)
Low gradient, lake outlet channel (C7)
Low gradient, lower valley braided glacial channel (D5)
Rocky estuarine channel (E2)

Channel Type Group 3

Low gradient, lowland muskeg channel (B2)
Moderate gradient, upper valley forest channel (B3)
Low gradient, alluvial fan forest channel (B5)
Moderate gradient, incised lowland muskeg/forest channel (B6)
Moderate gradient, deep gorge brush channel (B7)
Low gradient, lower valley, meandering glacial stream (D4)

Channel Type Group 4

High gradient, upper valley forest channel (A2)
High gradient, alluvial fan forest channel (A3)
High gradient, incised lowland muskeg channel (A5)
Low gradient, upper valley brush channel (B4)
Moderate gradient, upper valley glacial channel (D3)

Channel Type Group 5

Very high radient, mountain slope forest channel (A1)
High gradient, mountain slope cascade channel (A4)
Low gradient, cirque basin channel (D1)
Upper valley, glacial torrent channel (D2)
No streams present

[1] Source: USDA Forest Service. 1985. Aquatic habitat management program handbook. U.S. Dep. Agriculture, For. Serv., Alaska Reg. Juneau, Alaska. 80 pp.

In order to evaluate the suitability of a site as habitat for bald eagles, the suitability index values for each of the variables must be combined. Compensatory relationships between the variables are assumed to exist in this model. This type of relationship exists when a variable with marginal or low suitability is offset by the high suitability of other variables (USDI Fish and Wildlife Service 1981). The mathematical function that describes this relationship is the mean (or average value) of individual suitability scores. Geometric means typically produce a smaller score than arithmetic means because they are influenced more by low values for one of the variables. Geometric means are, therefore, used when the compensatory relationship is perceived to be weak (USDI Fish and Wildlife Service 1981).

The equation developed to generate the HSI for the breeding habitat of bald eagles is:

$$HSI = [((V_1 \times V_2)^{1/2})^2 \times V_3 \times ((2xV_4 + 2xV_5 + V_6)/5)]^{1/4}$$

Where HSI = habitat suitability index
V_1 = plant association group (V_{1A}) or forest type (V_{1B})
V_2 = stand age class
V_3 = distance to water
V_4 = foraging site conditions
V_5 = shoreline conditions
V_6 = stream channel type group

Strong compensatory relationships are assumed to exist between foraging site conditions (V_4), shoreline conditions (V_5), and stream channel types (V_6). However, foraging site and shoreline conditions are weighted more heavily than channel type group because they are believed to have a greater influence on food availability and, subsequently, on the quality of habitat. The relationship between plant association or forest type (V_{1A} or V_{1B}) and stand age (V_2) is believed to significantly affect the availability of suitable nest sites and is weighted to reflect the importance of these variables.

Sensitivity Analysis

An analysis of the sensitivity of the model was conducted to determine the responsiveness of the model to changes in the value of the variables (Wiens and Innis 1974). Each of the variables in the model were modified while the other variables were held constant. The results of these runs were compared to runs when all variables were held at the constant value. Sensitivity values (SV) were calculated using the method of Stalmaster (1983):

SV = [(modified output - control output)/control output]/
[(modified input - control input/control input].

Sensitivity values indicate which variables have the greatest potential to change the HSI values and give an indication how the model operates. Plant association or forest type (V_{1A} or V_{1B}), stand age

(V_2), and distance to water (V_3) have the greatest effect on resulting values (Table 6). Foraging site conditions (V_4) and shoreline conditions (V_5) have an intermediate influence on the evaluation of habitat suitability. Stream channel type (V_6) has the least relative influence on the HSI value.

Applying the Model

An HSI value determined by this model reflects the potential of a habitat to support breeding bald eagles in southeast Alaska. Relationships between HSI values and population numbers of breeding bald eagles may not be evident because populations may be affected by nonhabitat factors that are not included in the model. Correct use of the model involves comparison of: (1) the habitat's potential to support bald eagles at subsequent points in time; or (2) the potential of two or more different areas to support bald eagles at the same point in time.

The HSI model for the bald eagle in southeast Alaska has been programmed for use on the Data General System 8000 computer. Bald eagle nest data collected by the U.S. Fish and Wildlife Service on the Ketchikan Area, Tongass National Forest, is being used to test the performance of the model in evaluating habitat suitability. Results of the test will be reported in a separate document.

For more information on this program, contact the USDA Forest Service, Alaska Region Office, P.O. Box 21628, Juneau, Alaska, 99802-1628.

Table 6. Results of the sensitivity analysis of the Habitat Suitability Index model for the bald eagle in southeast Alaska. High sensitivity ratios (output change:input change) indicate variables that most influence the Index value.

Variable	Modification (percent)		Sensitivity Ratio
	Input	Ouput	
Plant association or forest type (V_{1A} or V_{1B})	90	44	0.49
Stand age (V_2)	90	44	0.49
Distance to saltwater (V_3)	90	44	0.49
Foraging site conditions (V_4)	90	11	0.12
Shoreline conditions (V_5)	90	11	0.12
Stream channel type (V_6)	90	5	0.05

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